Use of a High-Energy and Low-Pressure Energetic Source for Mine and Obstacle Clearing

Paul Gefken
Brian Peterson
SRI International
Poulter Laboratory
333 Ravenswood Avenue
Menlo Park, CA 94025
phone: (650) 859-6093 fax: (650) 859-2343 e-mail: prg@unix.sri.com

Award #: N0001498WX30035

LONG TERM GOALS

Past numerical and experimental work suggest that energetic charges that produce a low-level long-duration pressure pulse would enhance the damage to certain types of underwater structures, generate larger craters, generate larger volume bubbles, and generate larger water plumes than conventional high pressure explosives. SRI International has conceived a novel high-energy low-pressure (HELP) energetic source that has the potential to compliment the existing conventional and advanced high-pressure energetic charges used by the Navy. The HELP charge is not viewed as an explosive that will generally outperform other explosives, but rather an explosive for neutralizing targets that are particularly sensitive to low pressure long duration loads.

APPROACH

The HELP charge concept consists of an energetic source that generates an initial pressure spike through detonation of a small portion of the material followed by a low-pressure long duration pressure pulse due to rapid deflagration of the remaining material. This concept originated from experiments performed with SRI's patented dilute explosive tile (DET), which consists of PETN uniformly, mixed with polystyrene beads. DET can be tailored to produce peak detonation pressures on the order of 3 to 50 kbar and detonation velocities approximately half of conventional explosives. In tests performed with DET, it was observed that a significant amount of unreacted carbon residue remains after the detonation. The HELP charge concept entails adding an oxidizer to the DET matrix to produce rapid combustion of the unused carbon. This rapid combustion is expected to produce a low-pressure load (a few hundred psi) for a long duration (10 to 100 ms). The long duration results from a deflagration velocity of hundreds of m/s as compared to 5000 to 8000 m/s for conventional explosives.

The overall program approach consisted of first performing analysis to estimate the possible HELP charge performance followed by experiments to confirm the HELP charge performance. The analytical effort, which was completed in FY97, consisted of performing TIGER calculations to design a HELP charge mixture, performing one-dimensional hydrocode calculations to estimate HELP load levels, and performing two-dimensional hydrocode calculations to estimate the HELP charge lethal footprint for neutralizing SZ mines and obstacles. The primary conclusions from the analytical effort was that the HELP charge may produce a 35% increase in the lethal footprint for neutralizing Target E tilt rod SZ mines and SZ obstacles as compared to a M58 line charge with C4 explosive.

In FY99, the experimental effort consists of characterizing the HELP charge detonation velocity, constant volume pressure, underwater shock pressure-time history, and effects against a Type E tilt rod SZ mine.

WORK COMPLETED

The detonation wave speed in HELP charges was measured using ionization time-of-arrival (TOA) pins. Experiments were performed with uniform mixtures of PETN, polystyrene beads, and AP as well as with uniform mixtures of polystyrene beads and AP, which were detonated on an outside surface using Detasheet.

Five different HELP charge configurations were designed and tested, as shown in Figure 1: Configuration No. 1 consists of a uniform mixture of PETN, polystyrene beads, and an oxidizer. Configuration No. 2 consists of a uniform mixture of polystyrene beads and an oxidizer with PETN (in the form of Detasheet) located on a single outer surface. Configuration No. 3 is an extension of Configuration No. 2 in which multiple layers of Detasheet are used to maintain the detonation wave. Configuration No. 4 consists of a uniform mixture of polystyrene beads and an oxidizer with an internal core of PETN (in the form of a primacord). The final configuration, No.5, uses Detasheet wrapped around the periphery of a propellant. The basis for each design was to facilitate either a low detonation velocity (Configuration No. 1) or a material deflagration (Configuration Nos. 2, 3, 4, and 5).

Using SRI's water shock pool facility, experiments were performed to determine the HELP charge pressure-time history. Pressure measurements were made at multiple standoff ranges from the charge varying from 30.5 cm (12 in) to 243.8 cm (96 in) to study the attenuation characteristics of the pressure waveform generated by the HELP charge.

Tests were conducted using the best configuration from the screening tests to determine the tilt rod motion of Target E surf zone (SZ) mines due to HELP loads. We utilized 260% HELP charges with AP for all of the tests, since it was determined that this HELP charge produced the best late-time low-pressure performance. Tests with C4 explosive were performed to provide a benchmark for the tilt rod motion.

RESULTS

The detonation velocity tests showed that the HELP charges typically have a detonation velocity between 3280 ft/s (1000 m/s) and 11,483 ft/s (3500 m/s). These values need to be further reduced to facilitate generation of significant late-time low-pressure loads. The constant volume tests showed that the majority of HELP design produced the best overall constant volume pressure behavior with respect to generated pressure and efficiency of carbon material combustion. The 260% HELP charge also exhibited late-time low-pressure water shock characteristics. In one test, these characteristics wee extensive, but in the majority of tests, the lat-time low-pressure characteristics consisted of a buildup of pressure after the surface cutoff for a period of 1 ms. In general, the HELP charge late-time low-pressure performance needs to be further enhanced before it can be developed into a Navy weapon.

HELP and C4 charges were placed at standoff ranges of 18.0, 28.4, and 36.0 in. Two general types of tilt rod response were observed: 1) charge standoffs of less than 28.4 in. produced large tilt rod motion in the direction toward the charge location, and (2) charge standoffs of 36.0 in produced small tilt ro motion in the direction away from the charge location. The tilt rod motion due to HELP charges was greater than due to C4 charges in the close-in ranges. For example a 300-g C4 charges produced the same tilt rod motion at 28.4 in as a 260% HELP charge with an energetic weight of 166 g. This represents an explosive quantity savings of about 45%. The tilt rod motion toward the charge at this distance is a result of the tilt rod being engulfed by the bubble. When the bubble collapses, a jet of water is focused back toward the charge. The results indicate that the 260% HELP charge produces a larger bubble, which subsequently produces a higher velocity water jet upon bubble collapse. However, this enhancement only occurred when the tilt rod was located within the bubble, which represents a fairly small standoff distance from the charge. When the tilt rod was located outside the bubble, relatively little tilt rod rotation was produced by the HELP charge or the C4 explosive.

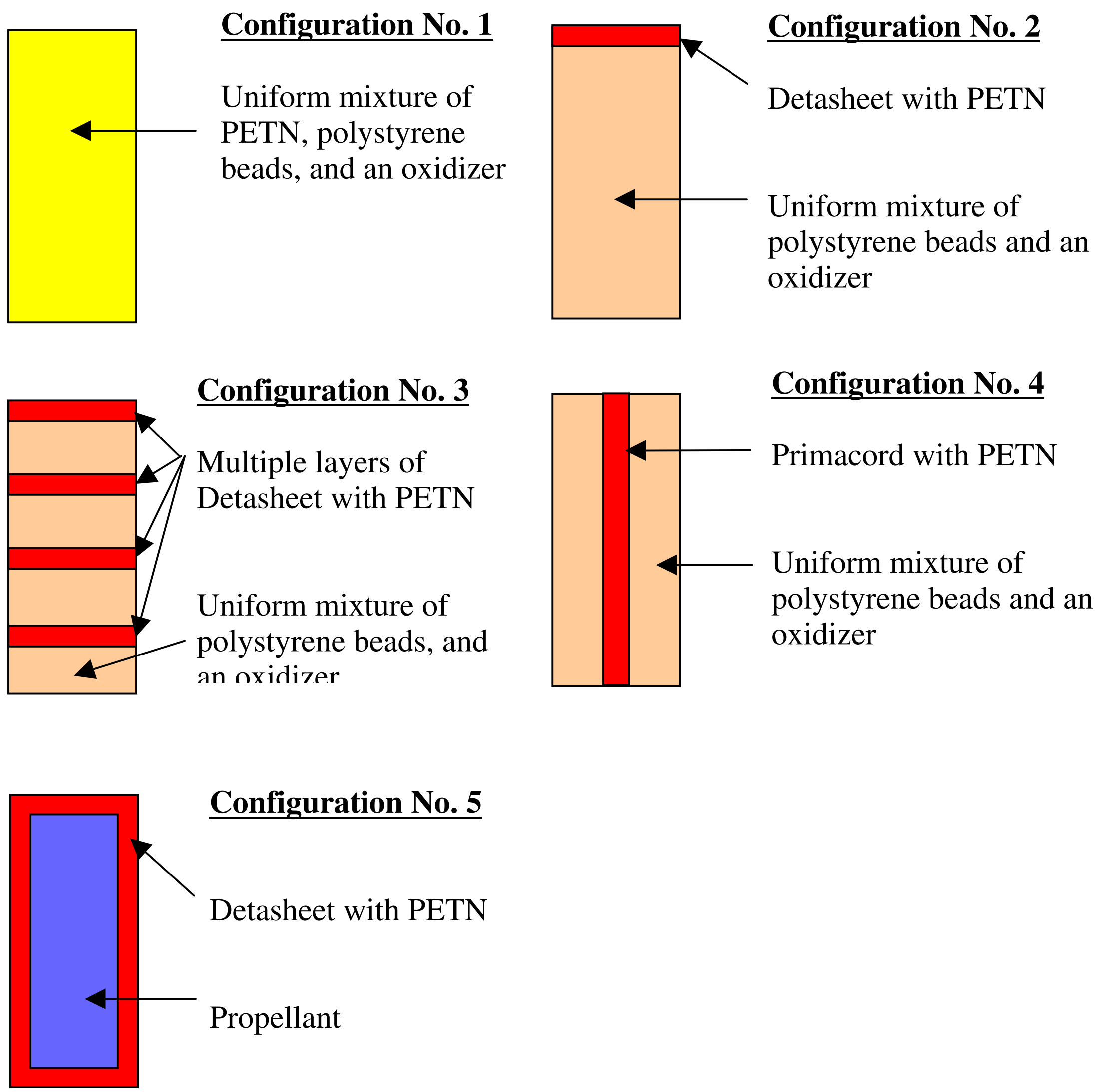

Figure 1. Help Charge Configurations

IMPACT/APPLICATIONS

The calculations performed in FY98 illustrated that the HELP charge may produce up to a 35% increase in the lethal footprint for neutralization of Target E tilt rod SZ mines and SZ obstacles as compared to a M58 line charge. Experiments performed have shown some low-pressure long duration characteristics that would support the computational results.

Other types of SZ mines and obstacles than the ones studied here may also be susceptible to HELP loads. For example, low pressure and long duration HELP loads may enhance the lethal footprint for neutralizing pressure plate mines by causing mine actuation in a manner as the mine was designed to operate. The increased bubble energy from a HELP source may enhance the damage to submarines due to the water jet phenomenology. Lastly, the HELP charge may produce larger plumes to provide enhanced protection of surface ships against low flying cruise missiles.

TRANSITIONS

No direct transitions at this time. The current formulations tried do not appear, based on the limited tests, to offer a significant improvement over existing explosives for the surf zone, mine clearance problem. Additional naval targets and problems are being considered for these formulations.

RELATED PROJECTS

ONR sponsors projects in improved energetic materials in 6.1, 6.2, and MANTECH programs. The proposed explosive is unique in that the load duration is significantly longer than other explosive under development.

PUBLICATIONS

Gefken, P. and Peterson, B. 1999: "Use of a High-Energy, Low-Pressure Energetic Source for Mine and Obstacle Clearing", SRI Project PYU-1919 Final Report, May.